Aura Observations: Enlightening our Understanding of How ENSO and the QBO Impact Trace Gas Composition

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Aura STM
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ENSO and QBO Variability

- The El Niño Southern Oscillation (ENSO) is the dominant mode of tropical tropospheric interannual variability (Philander, 1989).

- ENSO has been long known to cause significant perturbations to the coupled oceanic and atmospheric circulations (Bjerknes, 1969; Enfield, 1989).

- The Quasi-Biennial Oscillation (QBO) dominates the variability of the tropical stratosphere (Baldwin et al., 2001).

- The QBO induces a secondary meridional circulation impacting temperature and constituent composition.

- Satellite observations are enabling us to look at this variability in greater detail than ever before.

- An improved quantification of natural climate variations in observations is needed in order to detect and quantify anthropogenic climate trends.

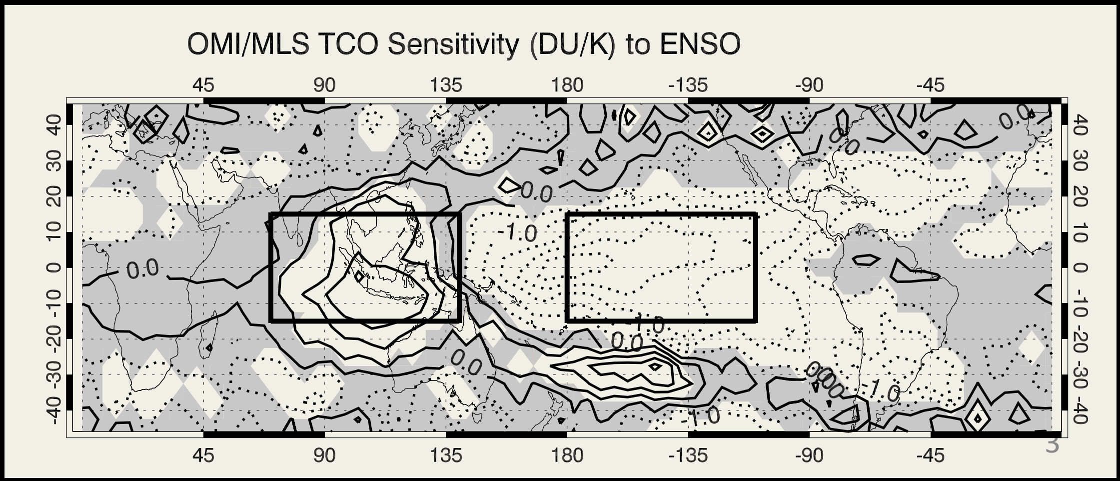
Measurements, Reanalysis, and Simulations

Aura Satellite measurements:
Microwave Limb Sounder (MLS) Level 2 Version 3.3 Aug. 2004 – Jul. 2014
Tropospheric Emission Spectrometer (TES) L3 V2 Sept. 2004 – Dec. 2009
Ozone Monitoring Instrument (OMI) L2 V8.5 Oct. 2004 – Dec. 2013
Aqua Satellite measurements:
Atmospheric Infrared Sounder (AIRS) L3 V6 Sept. 2002 – Jun. 2014

Modern Era Retrospective-Analysis for Research and Applications (MERRA)
Jan. 1979 – Dec. 2013

Goddard Earth Observing System Chemistry-Climate Model (GEOSCCM)
Using the combined GMI stratosphere-troposphere chemical mechanism

Tropospheric Column Ozone Response to ENSO from OMI/MLS residual

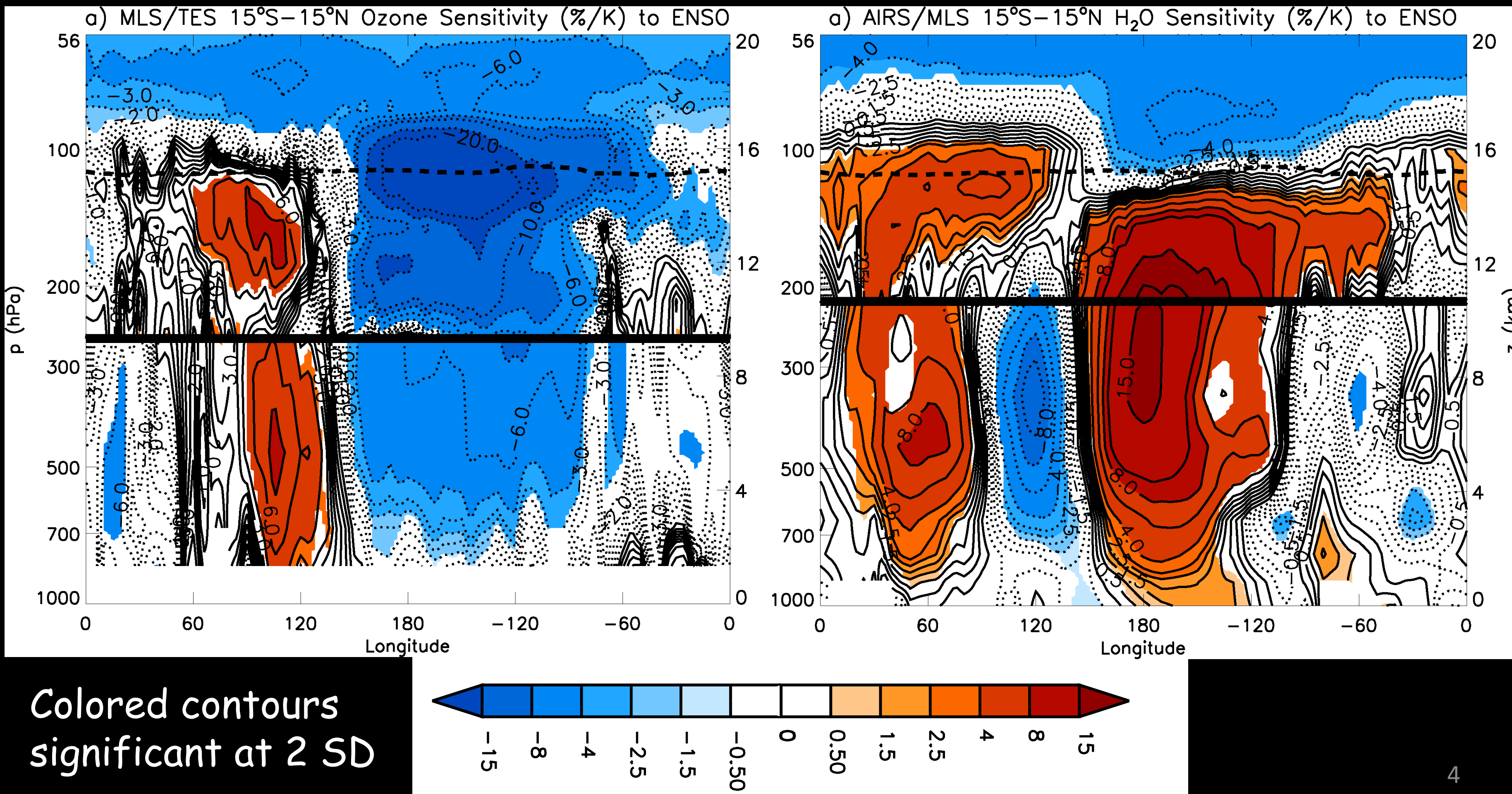


A Tale of Two Tracers

MLS/TES Ozone and MLS/AIRS H_2O sensitivity avg. over the tropics

Negative ozone and positive H_2O sensitivities are seen over the eastern and central tropical Pacific troposphere, in the stratosphere decreases in both

Positive ozone and negative H_2O sensitivities over Indonesia, except in UT



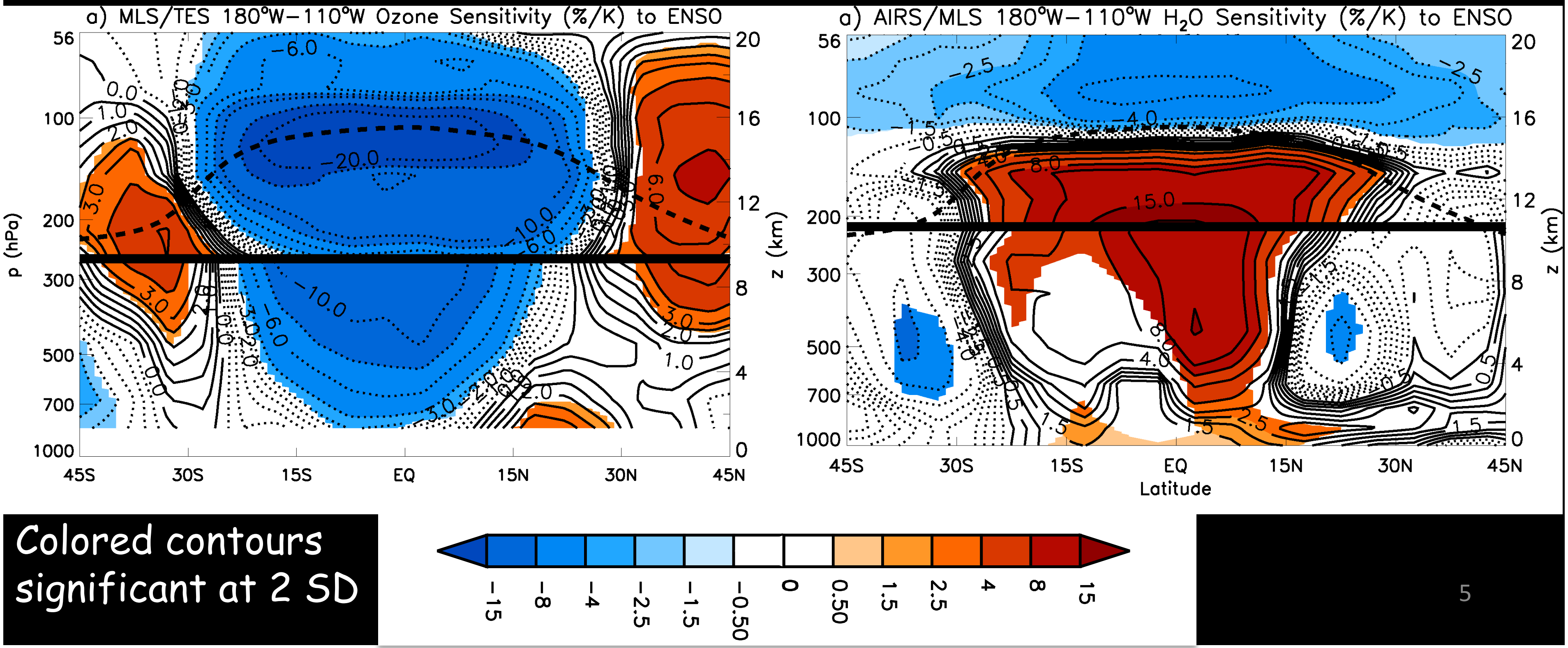
Colored contours significant at 2 SD

MLS/TES Ozone and MLS/AIRS H_2O sensitivity to ENSO averaged over Eastern and Central Pacific Region

In the deep tropical troposphere Ozone decreases and H_2O increases occur

In the midlatitudes increases in ozone occur in the UT/LS which continue into the troposphere in the subtropics, H_2O decreases with only small areas of significance

In the tropical LS ozone and H_2O responses are consistent with increased circ.

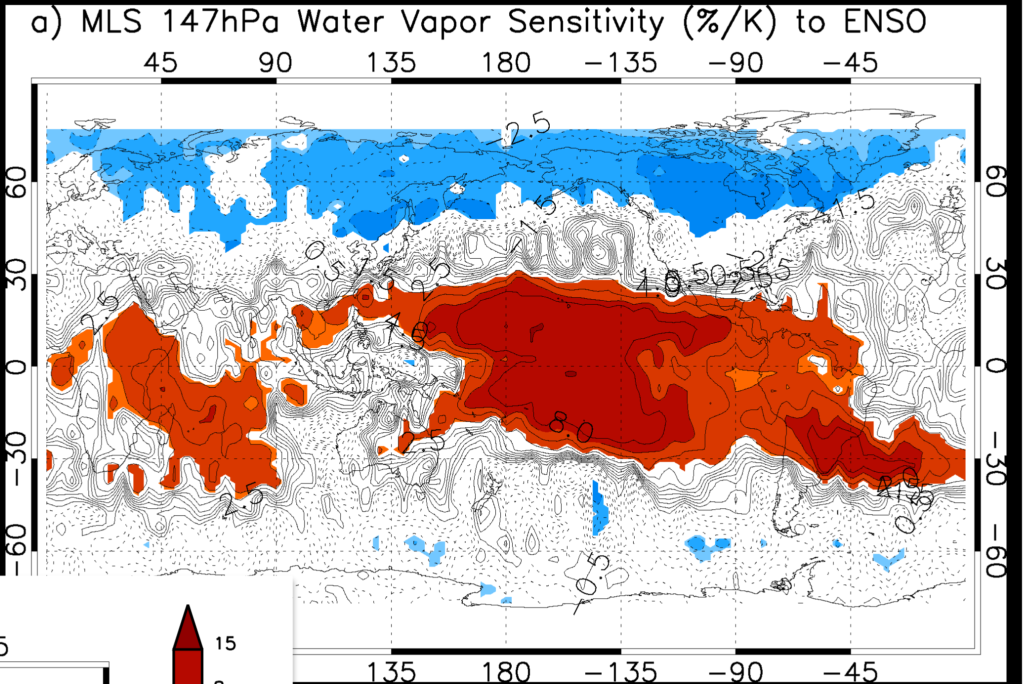


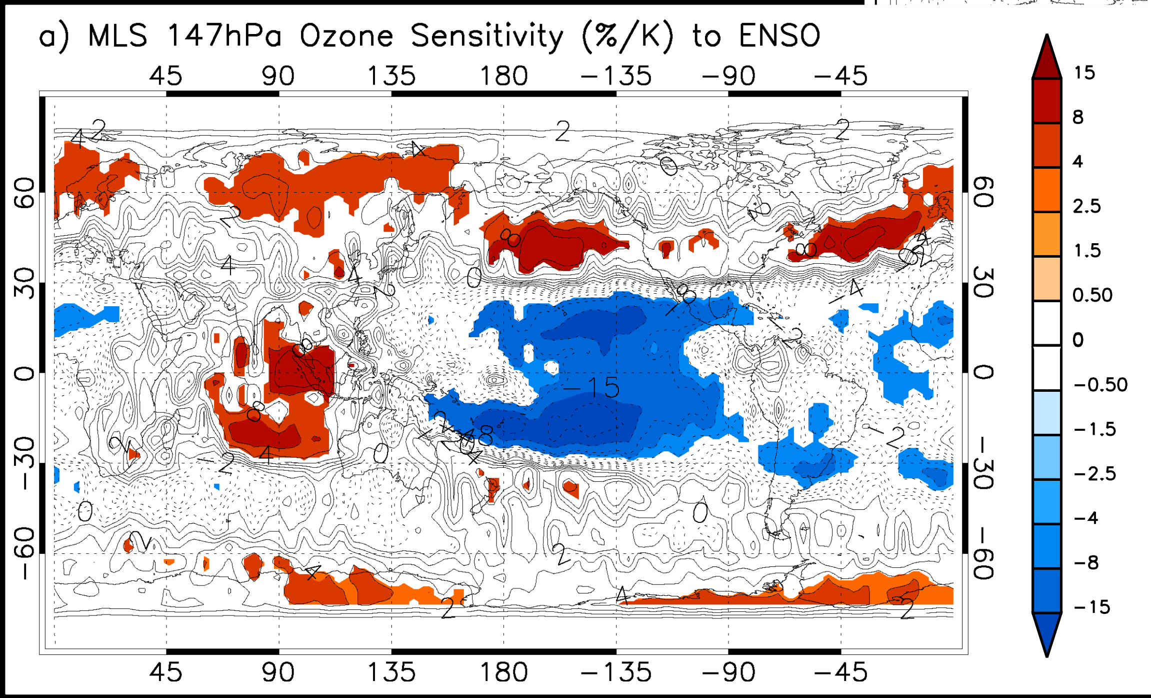
Colored contours significant at 2 SD

Horizontal Ozone and H_2O Sensitivity to ENSO at 147 hPa

Negative ozone and positive H_2O sensitivity over much of the tropical Pacific

Positive ozone sensitivity over Indonesia and tropical Indian Ocean with a mixed H_2O response





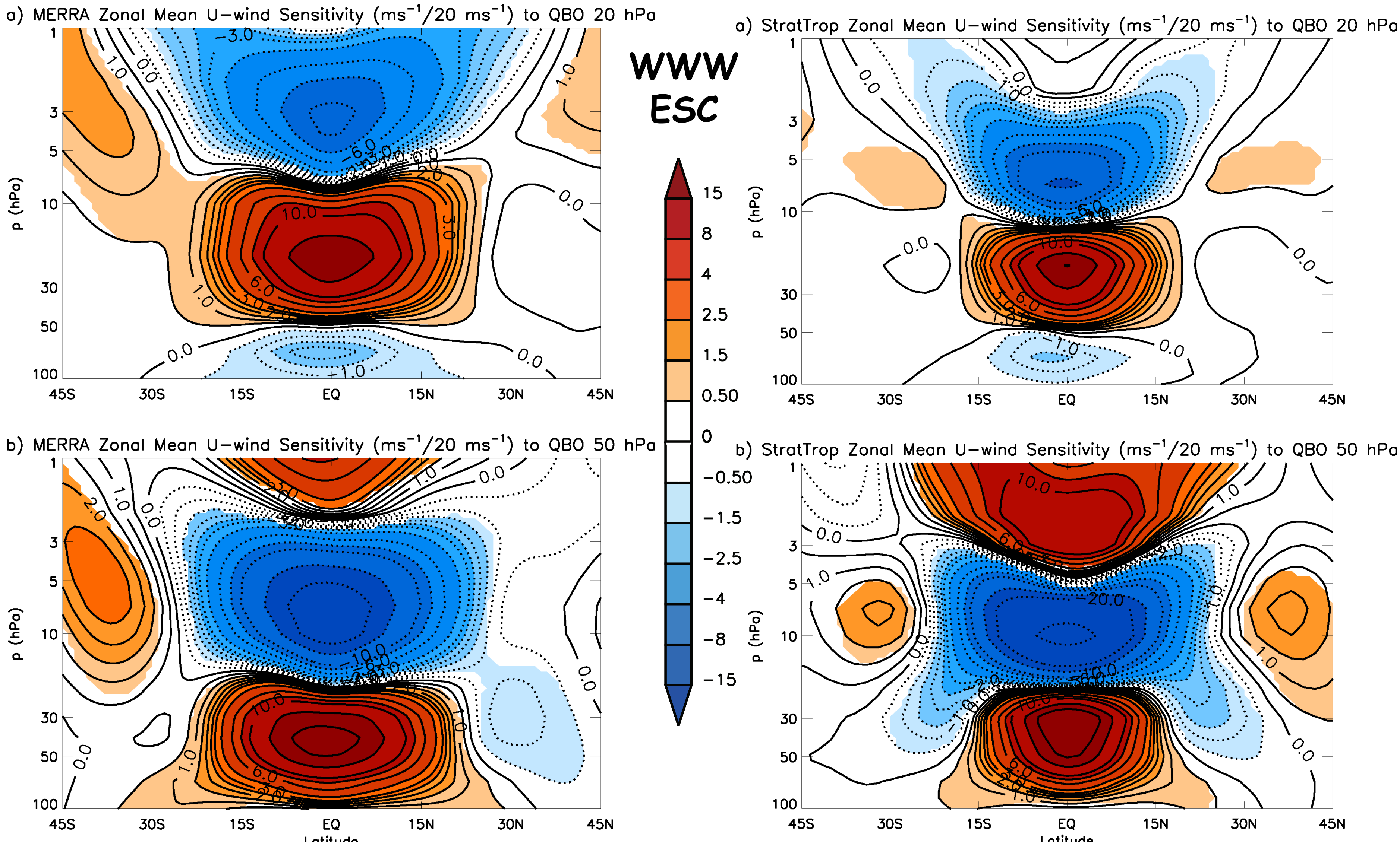
In the stratosphere H_2O response is negative with more significant response in the NH

Colored contours significant at 2 SD

U-wind response to the QBO at 20 and 50 hPa

Some QBO basics QBO wind vs. QBO wind shear

MERRA Reanalysis — GEOSCCM Simulation



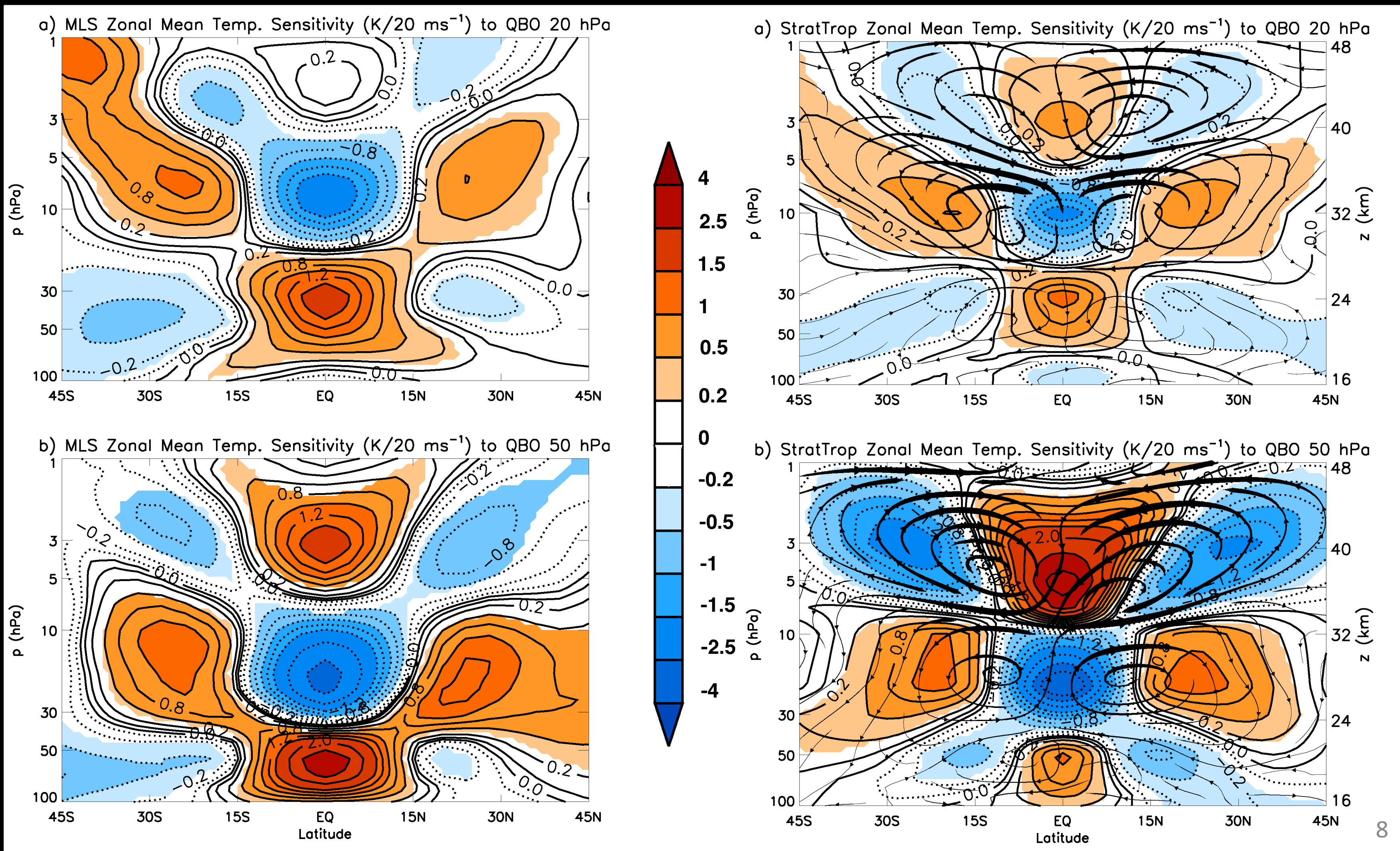
Temperature sensitivity to the QBO

The temperature response is showing dynamical changes to the residual vertical velocity (anomalous upwelling – cooling, anomalous downwelling – warming)

The secondary meridional circulation is shown as the streamlines

MLS Measurements

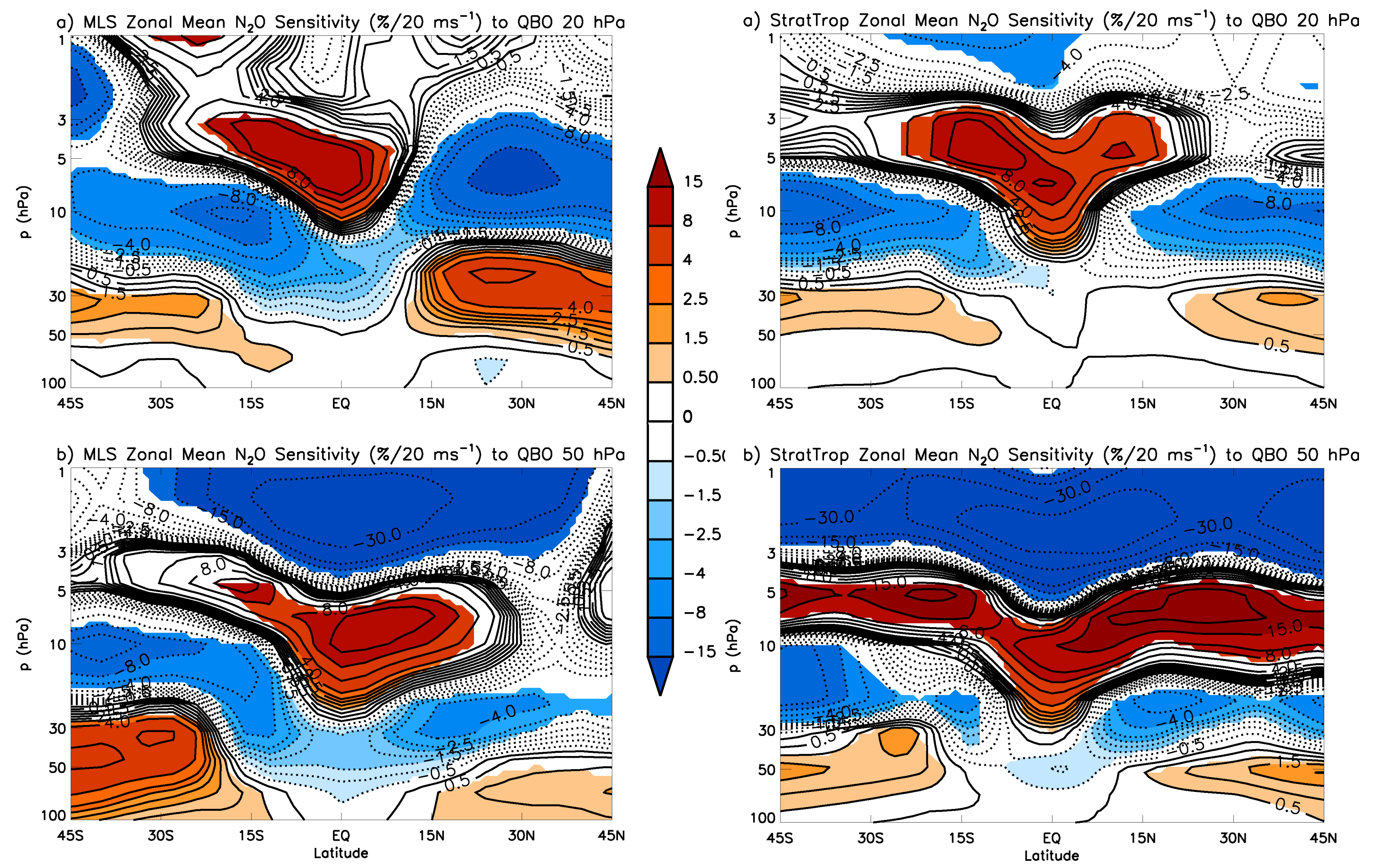
GEOSCCM Simulation



N_2O sensitivity to the QBO

Trace gas species like N_2O also show the secondary circulation response

MLS Measurements | GEOSCCM Simulation

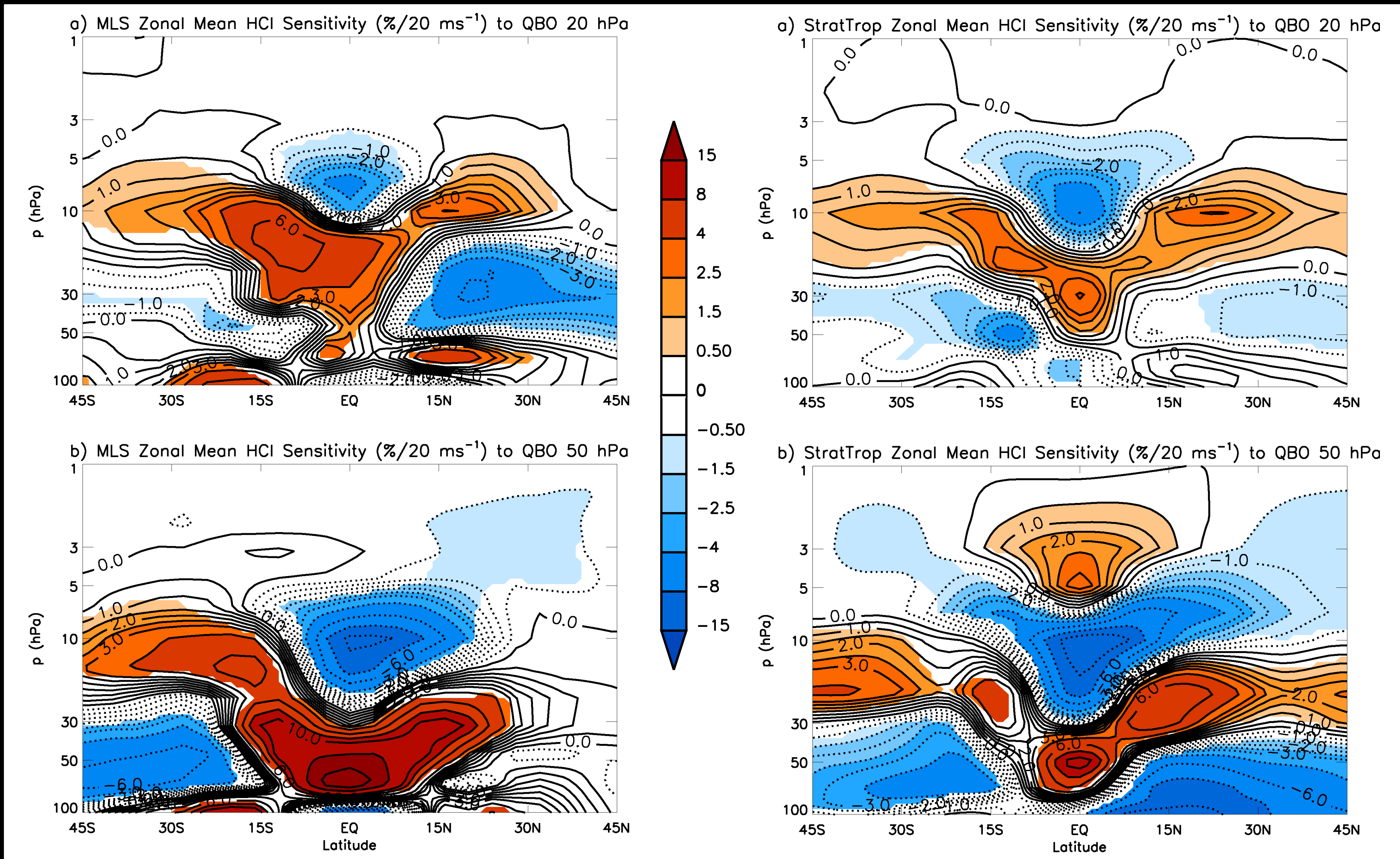


HCl sensitivity to the QBO

We can use tracers with different gradients to highlight different regions of the QBO response HCl has larger gradient in the lower stratosphere

MLS Measurements

GEOSCCM Simulation

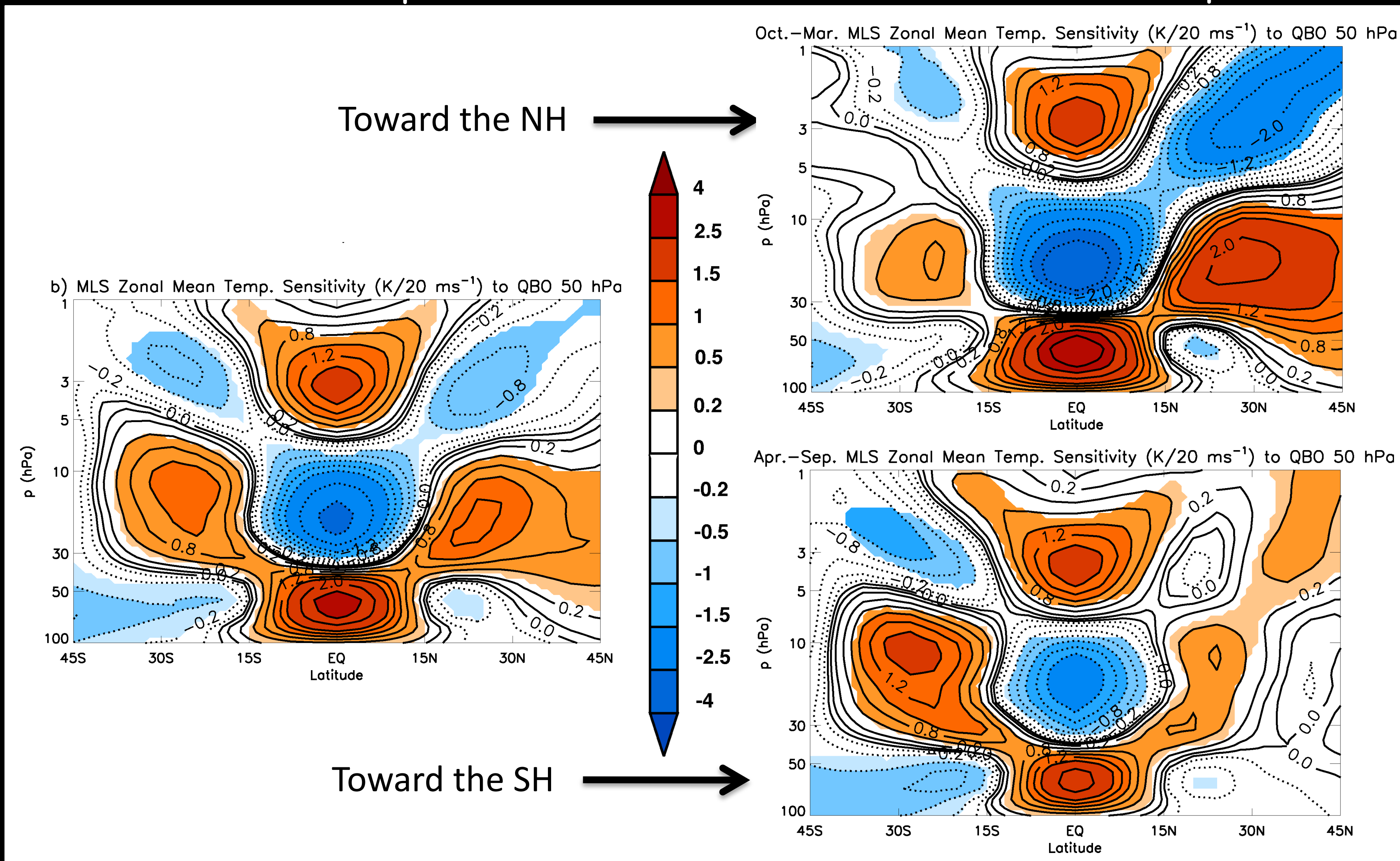


Seasonal Temperature sensitivity to the QBO

The secondary meridional circulation is active on the winter hemisphere side

This is visible in MLS temperature measurements when regressing seasonally

MLS Annual Response | MLS Seasonal Response



Conclusions

• ENSO and QBO variations are important drivers of tropical composition variability that can be quantified using satellite measurements.

• We can use information from multiple instruments MLS and TES for ozone and multiple satellites Aura (MLS) and Aqua (AIRS) H_2O measurements to derive the response from the troposphere into the stratosphere.

• The temperature and composition sensitivities derived from these measurements are useful for process understanding and model evaluation.

• They provide an improved quantification of natural climate variations which are needed to detect and quantify anthropogenic climate trends.

Reference

Oman, L. D., A. R. Douglass, J. R. Ziemke, J. M. Rodriguez, D. W. Waugh, and J. E. Nielsen, 2013: The ozone response to ENSO in Aura satellite measurements and a chemistry climate model, J. Geophys Res., 118,-976, doi:10.1029/2012JD018546.